63-3-2

The Committee on Fire Research

FINAL REPORT

July 1, 1959—June 30, 1962

Under
Contract CD-SR-58-45
Office of Civil Defense, Department of Defense

Supporting Participants: U. S. Forest Service,
Department of Agriculture
Department of Defense
National Bureau of Standards
National Science Foundation

Division of Engineering and Industrial Research
NATIONAL ACADEMY OF SCIENCES–NATIONAL RESEARCH COUNCIL
Washington, D. C.

THE COMMITTEE ON FIRE RESEARCH

FINAL REPORT

July 1, 1959 - June 30, 1962

Under
Contract CD-SR-58-45

Office of Civil Defense, Department of Defense

Supporting Participants: U. S. Forest Service, Department of Agriculture
Department of Defense, National Bureau of
Standards, National Science Foundation

Division of Engineering and Industrial Research

National Academy of Sciences-National Research Council

Washington, D.C.

The work of the Committee on Fire Research and
the Fire Research Conference will continue under
Contract OCD-OS-62-287

REPORT OF WORK UNDER CONTRACT CD-SR-58-45

Office of Civil Defense, Department of Defense
and
National Academy of Sciences

July 1, 1959 - June 30, 1962

Supporting Participants: U. S. Forest Service, Department of Agriculture, Department of Defense, National Bureau of Standards, National Science Foundation

The Contract

On October 14, 1955, the United States of America through the Federal Civil Defense Administration (to become the Office of Civil and Defense Mobilization and now the Office of Civil Defense, Department of Defense) negotiated a contract (CD-GA-56-38) with the National Academy of Sciences for work to commence December 1, 1955. A second contract (CD-SR-57-25) was written on December 1, 1956, and a third (CD-SR-58-45) on February 1, 1958.

The terms of all of these contracts are essentially the same. They request advisory and consulting services to the Government in the establishment and conducting of a research program on the spread and control

> "of large fires . . . through better knowledge and understanding of the fundamental factors involved. . . . . the establishment of a continuing group of experts drawn from appropriate fields of science and technology . . . . which would advise the Government on the formulation of a research program on the nature of mass fires and on means of dealing with them; on the acceptability of fire research proposals made to the Government; on the placement of research projects and competent research organizations; and on the progress of research projects and the adequacy and significance of their research reports."

The National Academy of Sciences is "to provide, through individual and staff contacts and through research correlation conferences, liaison and opportunity for voluntary coordination for research among the many agencies -- Government, academic, and industrial -- that are interested or active in fire research, and will thus help to guide the various research efforts to a common goal."

To clarify what was desired, the following points are pointed out but the contract states that the services are not to be confined solely to them:

1) Developing and maintaining a directory of fire research being done, where and by whom.

2) Organizing research correlation conferences on specific factors in fire research.

3) Providing the opportunity for the voluntary coordination of research among the many agencies -- government, academic and industrial -- that are interested or active in fire research.

4) Assisting in planning specific research projects.

5) Providing guidance for the placement of research programs or projects, and advising on the adequacy and significance of progress and reports.

Under the contract, a Committee on Fire Research, having nine members, and a Fire Research Conference, having thirty-four members to serve in an advisory capacity to the Committee on Fire Research, were established within the Division of Engineering and Industrial Research of the Academy-Research Council. The members of the Committee serve as ex-officio members of the Conference and Professor H. C. Hottel of the Massachusetts Institute of Technology is chairman of both the Committee and Conference. One representative from England and one from Canada serve as liaison, without vote.

At the present time the Committee and Conference are supported by the Office of Civil Defense, the U. S. Department of Agriculture through the Forest Service, the Department of Defense, the National Science Foundation, and the National Bureau of Standards.

A Proposed Fire Research Program

The National Academy of Sciences was requested to "provide consulting and advisory services to the Government in the conduct of the research program on the spread and control of large fires." The need to define an adequate program became the primary effort of the Committee on Fire Research and in the spring of 1958 it published "A Proposed Program for Fire Research." The Introduction of this Program states:

> "The Committee on Fire Research has studied the present status of fire-fighting techniques and strategies, and believes that our only hope for being able ultimately to cope with large fires lies in a major expansion of our fundamental research on fires.
>
> "The large volume of research on combustion properties of building and other materials, on fire-fighting equipment, and on fire prevention has produced significant advances in fire control. But such studies have left untouched several of the fundamental factors associated in a controlling way with the city conflagration or the forest fire. To point out how these deficiencies may be remedied, the Committee on Fire Research recommends a national program emphasizing those areas not already adequately covered by current efforts of military and civil agencies . . . .
>
> "The empirical approach is to try one idea after another to see which works best. Many of man's problems have been solved satisfactorily this way - sometimes quickly, and often without much understanding. The scientific approach is to build up knowledge of the problem from fundamentals, describing

> the situation so adequately in terms of the fundamental laws - for example, in fire problems, the laws of thermodynamics, fluid mechanics, and chemical kinetics - that the complete description of the problem itself leads to its solution. The method often seems very slow, but no other would have yielded some of the results to its credit. The scientific method lags the empirical one today in fire research."

These were the premises on which the Program was based. Fundamental research problems were defined and the Program was outlined in detail under four main categories: I. Laboratory Studies; II. Field Studies; III. Operations Research; IV. Ad Hoc Developments.

The Chairman of the Committee on Fire Research and Dr. Howard W. Emmons, a Committee member, presented the Program to Dr. James R. Killian, Special Assistant to the President for Science and Technology, and members of Dr. Killian's research panel. Dr. Killian then invited representatives of each of the Government agencies having an interest in fire research to a meeting on December 9, 1958, and the Chairman of the Committee on Fire Research and Dr. Emmons presented the Committee's Program and a Proposal for Support of Fire Research to them. (See Appendix A, Proposal for Support of Fire Research)

Due to lack of time at the meeting, it was impossible to reach definite conclusions concerning the proposals advanced by the Committee on Fire Research. Dr. Killian appointed a subcommittee from those in attendance at the meeting to formulate a statement outlining possible action by interested Government agencies in response to the need for furthering fundamental fire research, as outlined by the Committee on Fire Research. Mr. Gerald Gallagher of the Office of Civil and Defense Mobilization was chairman of this subcommittee.

The subcommittee recommended that:

1. The National Bureau of Standards be asked to assume responsibility for direct administration of Category I (see Appendix A) research, the coordination of fire research in the Federal Government, and the furtherance of the research objectives of the NAS-NRC Committee on Fire Research. They would, in addition, develop an appropriate system for the dissemination of fire research results.

2. The National Science Foundation should be asked to assist in a maximum way in supporting basic fire research and in underwriting desirable fire research conferences.

3. In due course, the Department of Defense and the Office of Civil and Defense Mobilization can be requested to allocate a starting fund for Category I research in FY 1960, and that the National Bureau of Standards be asked to seek appropriations for funding the work in FY 1961 and thereafter.

In the spring of 1959, the Committee on Fire Research wrote letters to twenty-two universities, fourteen Government laboratories, and nineteen private research laboratories, suggesting that they submit to the Committee proposals based on the Program, and offered to suggest suitability for National Science Foundation or other appropriate agency support.

Twelve proposals were received from universities, eighteen from Government laboratories, eleven from private laboratories. In judging these proposals, the Committee adhered to the principle of preserving the anonymity of the reviewer, set up three reviewing groups, pooled their

judgments, and passed its recommendations to the National Science Foundation for action.

Not all of the proposals were recommended. Some were inadequate, others needed pointing up through small adjustments and clarification. The National Science Foundation accepted some of them for support. Early in the fiscal year 1959, funds from the Department of Defense and the Office of Civil and Defense Mobilization were transferred to the National Bureau of Standards for support of fire research and many of these proposals which had been solicited by the Committee on Fire Research were submitted to the National Bureau of Standards for support from this special research fund.

The NSF and NBS continue to receive proposals. Some receive support. NSF supports those which meet its requirements. NBS has supported some with funds transferred from DOD and OCD. Others have been rejected because of insufficient funds.

Correlation Conferences

1956 First Correlation Conference "Fire Research"

1957 Second Fire Research Correlation Conference "Methods of Studying Mass Fires"

1959 International Symposium "The Use of Models in Fire Research"

Three hundred and seventy-two persons interested in fire research attended these three conferences planned by the Committee on Fire Research to stimulate and correlate work in fire research. Twenty-two were from foreign countries. The publications listed above report these Conferences and have been distributed widely in this country and abroad.

The first conference was planned to bring a variety of groups together. Presentations were made by panels; one panel representative of civil agencies, one of the military, one of scientists concerned with fire systems and models.

The second conference was planned for a group of individuals with fire-fighting and -prevention experience. It was intended for scientists to learn from practical fire personnel about problems of fire fighting and to give fire fighters some knowledge of the possibilities of the laboratory.

The third conference, "The Use of Models in Fire Research" was a result of discussions by the panel on fire systems and the use of models in the first conference. Five sessions were held, each on a different aspect of modeling: Modeling Principles, Liquid Surface Model Fires, Full-Scale Studies and Tests, Aerodynamics of Fires, Experimental Techniques. In all, fifteen papers were presented, including one each from Germany, Canada, and France, three from England and two from Japan. Prepared commentaries preceded and stimulated the discussions.

Technical Meetings

The Committee planned a series of Technical Meetings. The idea is to hold small informal meetings where limited research problems can be discussed informally and spontaneously. These meetings require no elaborate preparations or publication of material. They are intended to bring persons with specific interests together at a suitable place to discuss a particular problem area.

The first one was held at the Atlantic Research Corporation on the subject "Inhibition of Ignition of Flame with Chemicals"; the second at the

National Bureau of Standards on the "Use of Models in Fire Research"; and the third a combination of sessions at the U. S. Forest Service in Berkeley, California, and the Naval Radiological Defense Laboratory in San Francisco, California, on two subjects, "Thermal Degradation of Wood and Other Materials of Construction" and "Ignition of Wood by External Heating."

The Committee plans to hold the next Technical Meeting at Harvard University on "Aerodynamic Phenomena and Fires."

Directory of Fire Research in the United States

A Directory of Fire Research in the United States was compiled and distributed in June 1961. It is planned to revise the Directory every other year.

The research reported in the Directory includes all kinds of research that bears on the understanding and control of unwanted fires. Fifty-three research groups reported on two hundred and thirty-four projects and listed two hundred and seventy-five of their publications.

Fire Research Abstracts and Reviews

When the Committee on Fire Research and the Fire Research Conference were appointed early in 1956, one of the first tasks they undertook was a classification of fire research and an investigation of the literature. A working subcommittee reported that it found thousands of references in lists compiled by various agencies -- Army, Navy, NFPA, duPont de Nemours, and others. The British liaison called attention to a bibliography which the

Joint Fire Research Organization publishes and keeps in constant revision. The subcommittee produced a classification which was revised for use in Fire Research Abstracts and Reviews.

In the Report of the Year's work, December 1, 1955 - November 30, 1956, the following recommendation was included:

> "A survey of literature on fire research should be made extending from the present backwards in time, to constitute a preparatory step toward publication of a bulletin on current fire research. The Committee recommends that this project be given further study toward establishing a pattern of selection and definition of prime function. The Committee agrees that this survey should follow the classification pattern established by the subcommittee on classification."

An appendix giving further details was attached to that Year's Report and is attached herewith as Appendix B, Concerning Bibliography and Publication of a Journal. A subcommittee on the publication of an abstract bulletin was appointed and met on August 5, 1957. The publication of a journal for abstracting material on fire research was recommended.

Letters were then written to persons in industry, universities, and military and Government agencies asking for the names of possible abstracters. Sixty-seven abstracters, including nine in foreign countries now work on Fire Research Abstracts and Reviews. A liaison has been made with a scientist in the fire research field in Japan who selects and contributes reviews and abstracts from time to time.

Dr. Walter G. Berl, Applied Physics Laboratory, The Johns Hopkins University, is the editor of Fire Research Abstracts and Reviews and contributes his time without compensation.

The abstracts are classified under twelve categories: I. Ignition Phenomena, II. Thermal Decomposition, III. Heat and Material Transfer,

IV. Diffusion Flames, V. Combustion Principles, VI. Radiation, VII. Suppression of Combustion, VIII. Model Studies and Scaling Laws, IX. Atomization of Liquids, X. Meteorological Interactions, XI. Operational Research Principles Applied to Fire Research, and XII. Instrumentation.

Fire Research Abstracts and Reviews is issued three times a year (January, May, and September). The first three volumes (1959, 1960, and 1961) contained three hundred and seventy-eight abstracts, eight reviews, and seven papers. Sixteen hundred copies of each issue are distributed. Copies are being sent to twenty-four foreign countries: Argentina, Australia, Belgium, Brazil, British Columbia, Bulgaria, Canada, Denmark, England, Finland, France, Germany, India, Israel, Italy, Japan, Netherlands, New Zealand, Philippines, Russia, Scotland, Spain, Sweden, Switzerland; to two hundred and eleven individuals in these countries.

"A Study of Fire Problems"

The recommendations of Mr. Gallagher's subcommittee appointed by Dr. Killian were contingent on obtaining funds for support. These had been less than hoped for and on June 17, 1960, the subcommittee met to discuss what could be done about it. In the course of the discussion, it was said that a summer study group should be brought together in 1961 to look at the overall fire problem.

The Committee on Fire Research held a meeting on September 14, 1960. Quoting from the minutes of that meeting:

"A summer study was recommended by the subcommittee on Fire Research (Mr. Gerald Gallagher, OCDM, Chairman) appointed in December 1958 by

Dr. Killian, then Special Assistant to the President for Science and Technology. The subcommittee's recommendation was made at a meeting held on June 17, 1960 and it read as follows-

'The National Bureau of Standards will request the National Academy of Sciences to sponsor a summer study (symposium) on fire research during 1961. National Bureau of Standards will budget for this symposium in its FY 1962 budget. In addition to appropriate U. S. scientists from various fields of research, invitees would include industry representatives and members of foreign fire research organizations.'

"Accordingly, Mr. D. E. Parsons, Chief of Building Technology Division of the National Bureau of Standards wrote to the Chairman of the Committee on Fire Research on August 12, 1960."

Representatives of the National Science Foundation attended this meeting of the Committee on September 14, 1960, endorsed the summer study, and stated that previous summer studies such as the one proposed had had very fruitful effects; fresh new approaches had been arrived at, key people had been educated by people with different points of view. The Committee on Fire Research agreed to accept the responsibility of the summer study and the National Science Foundation indicated its willingness to support it. Dr. Howard W. Emmons of Harvard University agreed to be chairman of the study.

Woods Hole, Massachusetts -- July 17 - August 11, 1961

The summer study was held at the National Academy of Sciences-National Research Council at the Whitney Estate in Woods Hole.

Early in the planning the Chairman of the Committee on Fire Research made the statement: "Such a study stands or falls on the quality of the participants."

The following is quoted from the opening speech of the Chairman of the Committee on Fire Research.

". . . . . I have never before participated in one of these summer group studies of which there have been quite a few,-some very successful. I understand that open-mindedness is a prized attribute, and this must be especially true on a problem which has been around so long that the way of doing things has become well established. I understand further that ideas are best generated in an uncritical atmosphere in the early stages of their generation. I have never been certain of this generalization; different minds respond best to different kinds of stimuli. But we must remember that most of the members of this group are not fire experts, that their tendency to generate ideas can be curbed by too much of the 'we tried that and it didn't work' reply. I do not mean that such critical comments should be suppressed forever; but let's delay them.

"We have the good fortune to be briefed this week by a group of men of outstanding position and knowledge in the fields of fire. They will pardon us if we sometimes question the basis for some of the generalizations made or doubt the adequacy of facts to support them. Let's remember that our differences are from the head and not from the heart."

Dr. Randal Robertson, Associate Director (Research), spoke for the National Science Foundation.

". . . . . You may wonder why a Federal agency such as the NSF, whose responsibility is basic research and education in the sciences, should be concerned with the question of fire research which is a problem on the applied side compared to ivory tower pure science on the other extreme. I think the reason that NSF is concerned with this is that an agency such as ours

which is responsible for basic research must also be concerned that the results of research find prompt application in meeting the many problems and needs that our country has, not only in defense but across the board. We have to be sure that every effort is being made to apply the knowledge obtained in basic research to these problems and to make sure that the country is getting the maximum benefit from science. It seems to me that the fire problem is a very good example of a major national problem which needs a careful look _ · the point of view of science. We need to look hard at this field to make sure that all the resources of knowledge that we have are mobilized to meet the problem. The easiest thing to do, probably, is to make up a list of areas of basic science that are relevant to fires. You can do this in about half a day and come up with aerodynamics, meteorology, chemical kinetics, and so on, and you can say that if we are to get on broadly with this sort of problem we must stimulate basic research in all these fields and this is true and this is great and we are supporting research in all these fields and would like to support more. But in itself this is not enough; basic research, the accumulation of scientific knowledge alone, will never solve the practical problems that we face on a day by day basis. You cannot solve them in the long run without this; on the other hand, they do not solve themselves by the accumulation of knowledge. You have to have people who are dedicated to putting knowledge to work in the particular field of concern, people who provide the essential transition from science to the technological and operational problems that you face in a field of this kind.

". . . . . The day is past, I think, when Yankee ingenuity and common sense could cope with technological problems. We still need these, but full

advantage must be taken of modern techniques, of operations research, simulations systems analysis and other methods and tools of approach to this transition problem which probably are still to be developed. Now this summer study is an effort to bring people with varying points of view (scientists, engineers, operations people) together to look at the overall problem, to look at the state of the art, to look at the potential for application of scientific knowledge to formulating the needs in terms that will reflect back into the research and development program."

Briefings. During the first two weeks, the participants were briefed by experts from all parts of the country on a great variety of interrelated subjects: city, forest, industrial fire statistics and their collection and organization; chemistry of combustion and fire inhibition; fire meteorology; fire and ecology; fire-danger rating; work of the Underwriters' Laboratories; cost of fire protection, city and forest; fire extinguishment in materials; fire extinguishment in forests; fire department organization and fire-attack planning, city and forest fires and in industrial plants; training of professionals, city and forest; meteorological instrumentation; control burns; equipment development, including detection devices, city and forest; prefire planning in cities and forests; physiology of burns and asphyxiation. Discussions on the briefings were held daily.

During the third week representatives of various Government agencies spoke on their interest in fire problems: Civil Defense, Department of Defense, National Bureau of Standards, National Science Foundation, U. S. Forest Service. Dr. Berl, Editor of Fire Research Abstracts and Reviews concludad this series by presenting a survey of present fire research.

Panels. At the end of the first week the participants divided into three panels based on their interest in problems of three general categories -- economic aspects, operational and organizational aspects, and fundamentals of fire phenomena. These groups continued throughout the study.

Writing the Report. In general, each panel group wrote those parts of the report which concerned its category. Checking and rechecking between individuals in all categories took place, followed by discussion before the entire group of participants. It should be noted that these participants served as individuals, not as representatives of their parent organizations and they spoke for themselves and not for their organizations. This gave the participants a kind of "academic freedom" which added to the value of the report.

The Report - "A Study of Fire Problems" (National Academy of Sciences Publication 949)

This report should be read as a record of the work during the summer study and its conclusions and recommendations are those of the participants in the study.

On October 3, 1961, the Committee on Fire Research met, reviewed the report, discussed the conclusions and recommendations and approved the report for submission to the Chairman of the Division of Engineering and Industrial Research for submission to the National Science Foundation by the President of the Academy. A copy of the conclusions and recommendations is attached as Appendix C.

On October 13, 1961, the Chairman of the Committee on Fire Research and Dr. Emmons, Chairman of the Summer Study, were invited to address a meeting of the Federal Council for Science and Technology on the work of the summer study group, its conclusions and recommendations.

Briefly the Chairman of the Committee on Fire Research said that the Committee had approved the recommendations in their present form, had rejected the concept of restricting the new Fire Office activities to re-research, expressed its views as to the optimum order of activation of the 11-point program, expressed a preference for the new group - possibly called the National Fire Office - being set up in the Department of Commerce but preferably not within the Bureau of Standards, and emphatically insisted on the new head of the Fire Office being a scientist or engineer of high standing.

Three million dollars was thought by the Committee to be a reasonable amount for a starting budget. Stress was given the recommendation for the effective use of existing agencies with fire interests, with monitoring and funding of at least a portion of the fundamental research to the National Science Foundation.

The Federal Council for Science and Technology has referred the report, "A Study of Fire Problems", to the Department of Commerce for consideration of its conclusions and recommendations. In the office of the Assistant Secretary for Science and Technology, conferences are being held with the Bureau of the Budget and plans are being made to present these matters to the next session of the U. S. Congress.

On June 14, the Chairman of the Committee on Fire Research and the Fire Research Conference called a meeting of the Fire Research Conference to discuss the report and identify areas of agreement, national or local needs in the fire areas which were not recognized or included in the report, and research areas which are not receiving deserved attention. The Chairman appointed

a subcommittee of Government connected Conference members having fire research interests for the purpose of studying the report, looking at what is recommended, assessing the reaction of their respective agencies to the recommendations, deciding how much of this should be done, and what the priorities should be. The report of the subcommittee which will be submitted to the Fire Research Conference will include an emphasis on the work presently being done in the various agencies and an indication of how this work fits into the overall program as recommended.

Respectfully submitted,

H. C. Hottel, Chairman

Appendix A

A Proposal for
Support of Fire Research

The N.A.-N.R.C. Committee on Fire Research, operating with joint support by the Office of Civil and Defense Mobilization, the Department of Defense, and the Forest Service, prepared a comprehensive outline of fire research, emphasizing the problem areas.* That outline did not indicate any order of procedure, or any division between research oriented toward understanding fire phenomena and research with a specific application in mind. There is little reason why one government agency should have a greater interest than another in those fundamentals of fire phenomena which it is hoped will ultimately aid in planning more effectively to cope with fire. Consequently, it appears appropriate for interested agencies to consider joint support of at least a portion of research in this category. In the fields of research with specific applications in mind, however, it is possible to identify specific problems with specific agencies. Recommended programs of research in these two categories follow:

I. Fundamental Research on Items A-G of the N.A.-N.R.C. Fire Committee Proposed Program (See Appendix for listing of those items)

Research in this area is best done by individuals rather than teams, will often be on a modest level of support ($20,000-$50,000/yr), can in some measure be associated with doctoral research at universities. The NA-NRC Committee considers one of its chief functions to be the encouragement of able research scientists to undertake such work, amd feels that problems in this category are susceptible of attack in so many different ways as to make multiple small-scale attack at many centers desirable.

It is quite feasible to spend several millions per year on research in this category, but there are two good arguments in favor of a much more modest start: (1) the number of scientists competent and interested in this field is limited; (2) fire research is not a field justifying the higher cost per bright idea that is associated with a crash program. It is suggested that the following agencies have interests which justify their support of this fundamental fire program at an annual rate of $50,000 to $100,000 each, for a total of $500,000 per year:

Army
Navy
Air Force
Office of Civil and Defense Mobilization
Armed Forces Special Weapons Project
National Aeronautics and Space Agency
Atomic Energy Commission

---

*See Fire Research Abstracts and Reviews, Vol. I, No. 1, pp 4-8 September 1958

It is further suggested that a single agency is better able to administer an integrated program than all seven agencies acting separately. It is therefore recommended that the above $500,000 be transferred to the National Science Foundation or to one of the Armed-service Research Offices (ONR, OOR, OSR).

II. Additional Fundamental Fire Research which should be carried on directly by Government Agencies.

A considerable effort of some twenty government laboratories and research-support offices presently goes into fire research. The NA-NRC Fire Committee believes this research is in general of good quality and justified; but it also believes that the program is in need of being supplemented by additional research of a more fundamental character, - research that makes more use of modern developments in heat transfer, combustion, fluid mechanics, and computational methods. Some fundamental work of considerable significance has been underway for some time. Research on inhibitors, for example, is believed already to be at an adequate level of support.

Much of the proposed new research would be oriented too directly toward end use to merit inclusion in category I above. There follows a list of problems on which additional support is recommended. After each problem there are indicated (1) an agency with appropriate research facilities and demonstrated competence in the field, (2) an agency or agencies having extensive interest in the problem, (3) suggested level of annual financial support.

Problem	Working Agency	Interested Agency	Suggested Level of Support
1. Modeling Homogeneous Complexes (forests and built-up city areas) for study of fire front movement.	Forestry	OCDM AFSWP	$200,000
2. Collection and analysis of Field Data on fire spread.	Forestry	OCDM	$500,000
3. Interaction of fire with the atmosphere (model and full scale studies)	Weather AEC	Forestry OCDM	$500,000
4. Development of instrumentation for Field and laboratory fire research	Weather Air Force Bu. Stds. N.A.S.A.	Forestry OCDM DOD AFSWP	$300,000
5. Development of Model Laws of small fire systems and Improvement of generalizations coming out of work of fire partition manufacturers and other laboratory groups involved in empirical appraisal techniques.	Bu. Std. Bu. Mines	Army Navy Air Force N.A.S.A.	$200,000
6. Modeling of fires in enclosures	Bu. Stds Bu. Mines N.A.S.A.	Navy	$200,000
7. Operations Research on Fire Fighting a) Applied to Federal properties, e.g., Wash., D.C., NOTS b) Encouragement, with Federal funds, of operations research in cooperation with large city fire departments.	Army Navy Air Force Forestry	OCDM	$200,000
		Total	$2,200,000

The Need for a National Fire Agency

There presently exist a number of agencies charged with functions of correlating and/or sponsoring research on fire. One of these is the NA-NRC Committee on Fire Research. That committee has held two large Correlation Conferences on Fire Research and has recently initiated publication of Fire Research Abstracts and Reviews. The Committee stands ready to serve any useful purpose in this field; but is apparent that if the field is to develop properly along lines suggested by the Committee in its Research Outline and in the present Research Proposal, more time is needed than can be contributed by a committee of individuals meeting occasionally. One example may be given of the present inadequacy of fire research administration in the U. S. The United Kingdom, through its Joint Fire Research Organization maintains a punched-card record of every fire in the U. K. which requires fire brigade attention; and it maintains an organization for analysis of this information and dissemination of conclusions therefrom. Operations research is developing out of this activity. The NA-NRC Fire Committee feels strongly the need for similar activity in the U. S., but the task is enormous and no existing government agency appears to be suitable for it. The Committee is happy to continue its work, but would welcome the strengthening of fire research in the U. S. by the formation of a Fire Research Agency.

For the NA-NRC Committee on
Fire Research

H. C. Hottel, H. W. Emmons

Appendix to Appendix A

APPENDIX

(From a report of the NA-NRC Committee on Fire Research)

"In the following paragraphs, the areas in which basic studies would contribute most significantly to understanding of fires are elaborated.

"A. The convection of air and hot gases associated with a liberation of heat has two aspects: the general rising air currents and the local gas movements in and near the heat source. The general motions are gravity currents modified by interaction with winds, topography, density gradients, and turbulence. The local motions are driven by the general motion but are modified by gravity and gas expansion associated with combustion. The quantitative and in most cases even the qualitative features of these convection currents and their interaction with the burning processes are unknown.

"B. Inadequate information is available on gas and flame emissivities as a function of frequency at high temperatures. Mathematical techniques also must be developed for prediction of the radiation emitted by distributed sources and transmitted through absorbing gases. These data and techniques are necessary in order quantitatively to determine the radiant heat transfer which has a large influence on the rate at which fuel becomes available to the fire.

"C. Many fundamental questions are raised by the addition of suppressants to fires. The thermochemistry of suppressants in solid matter combustion has up to now been only superficially examined. Cooling, smothering, and direct chemical kinetic action (particularly in the case of water suppressant) should be critically examined in order to define and understand their actual roles; the ways in which the fundamental physical and chemical phenomena of fires are altered.

"D. Fundamental information on the aerodynamic properties of burning bodies in motion is needed. Available scanty information indicates that burning decreases drag. The magnitude of this effect and its connection with the aerodynamic pickup and transport of embers is unknown.

"E. The mechanism and thermochemistry of pyrolysis and oxidation of solid combustibles should be studied. The process involves heat and mass transfer coupled with endothermic and exothermic reactions within the solid phase. Gas evolution and transport away from the surface, and heat transfer to the surface from the burning gases, are also involved.

"F. The model laws for aerothermodynamic systems in which the fuel consumption rate is dependent on and is controlled by the heat evolution rate should be determined. This is a large and important field, essential for an understanding of fire phenomena. Parameters to be studied include effects of geometry, fuel type, radiation, and heating rates. Types of fire-front propagation should also be studied, e.g., continuous flame fronts or discontinuous sources of ignition distributed by aerodynamic forces.

"G. Fundamental studies of sprays should be extended to yield further quantitative data on the behavior in environments typical of fire situations. Studies should include evaporation rates, distribution of droplet sizes, jet characteristics, entrained air. Also included are the factors influencing stability and effects of sprays on aerodynamic and physical properties of the medium into which the spray is injected."

APPENDIX B

Concerning Bibliography and Publication of a Journal

The Committee on Fire Research of the National Academy of Sciences-National Research Council desires assistance in the preparation of a Journal, probably to be issued quarterly covering research of significance in building up a more adequate scientific understanding of the combustion process as it goes out of control - referred to hereafter for brevity as "fire".

There is no desire to compete with existing organizations in presenting a comprehensive bibliography including all aspects of the fire problem. Building codes, testing of structures to establish their meeting of specifications, description of fire incidence, empirical testing of extinguishing techniques - these are all examples of the coverage which should not be attempted. Although a precise statement of what is to be covered is the job of the contractor, the Committee's general interest is indicated by the desire to cover the following: Any papers which advance ability to generalize the description of fire, i.e., papers which present significant data correlations and simplify the process of quantitative identification; survey papers on flame propagation, particularly on the effects of additives; the structure of jet flames; allowance for buoyancy in treatment of the fluid mechanics of combustion; the "modeling" of combustion processes which can go out of control, with particular reference to interaction between heat generation in the flame and feed of fuel to the fire; occasional statistical data on the incidence of fire; operations analysis as applied to fire-fighting; mechanism of fire spread; mechanism of fire extinguishment.

It is proposed that the Journal be in two sections. The first will comprise a selected bibliography and abstracts on "fire science" and, somewhat after the manner of Chemical Abstracts, will carry a one-to-four sentence abstract. To solve the problem of coverage of current research and at the same time build up a bibliography of past research of significance, the Journal will for several issues carry an Appendix in which coverage of the past two decades is slowly accomplished - greatest weight of course being given to more recent work, and inclusion of a paper twenty years old being conditioned on its position as a classic in its field. The second section will consist of a few fairly comprehensive summaries of papers of outstanding interest. As with the first section, there will for some time be a section of older papers as well as the current paper review. It is anticipated that after completion of the survey of past literature, the Journal will decrease to perhaps ten pages, and cover no more than 100 papers per quarter.

January 10, 1957

From "A Study of Fire Problems"

APPENDIX C

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

During the course of the summer study on hostile fire, certain features of the overall fire problem have been clarified in the minds of the participants; the purpose of this section is to discuss these features briefly.

The problems of fire suppression and prevention have been under study for a great number of years by a wide variety of private and governmental organizations, and at the present time some 20 million dollars are spent annually in fire-related research and development work in the United States. However, most of this effort is applied work, a good deal of which is directed toward problems of satisfying code requirements and finding remedies for very specific problems. In addition, because the effort is supported by a wide variety of organizations, the direction of the total effect is diffuse, and areas of economic interest to the whole nation are often of insufficient interest, to any one group, to produce a desirable overall level of attention.

The consensus of the summer study group is that a fire group should be established within the structure of the Federal Government to ensure that the national effort is a balanced one. This group would have as its prime functions the following:

1. The continuous assessment of the complete program of fire prevention and suppression, including the fire-related research and development work being carried out in the nation.

2. Based on the assessment of the national effort, the group should arrange for the execution of work not adequately supported. Where possible, this arrangement should take the form of encouragement and/or financial support to the private and public organizations already carrying out work in the deficient areas. Where necessary the fire group should actively support new work either by contract with existing organizations or by work within the organization of the fire group itself.

To carry out these functions effectively, the fire group should consist of a staff of technical people who devote full time to the project. Although the use of consultants and advisory committees may be desirable, the existence of a permanent organization with full-time director and technical staff is necessary. Of equal importance is the assurance of a budget which would permit a sustained effort.

An attempt has been made to estimate a reasonable budget for the fire group. It is felt that an initial annual expenditure of about three million dollars would be required. Of this sum, approximately one-third would be spent on fundamental research problems, one-third on problems associated with obtaining information of a fundamental and applied nature from large-scale controlled or natural burns, and one-third on studies of fire-related problems in the areas of economic and operationsl research. As the program develops, greater effort in these areas would be possible, and problems of an applied nature could be attempted in following years. The sustained effort required to support this fire group work may become as great as three times the initial effort.

It should be emphasized that the study group was aware of the efforts presently being made in industry and by government groups to support and encourage fire-prevention and -suppression work. One of the major functions of the proposed fire group should be to stimulate such work; and where feasible, the resources of these organizations should be used in carrying out the proposed program.

The purview of the fire group should include all aspects of the fire problem. Thus, the group should be free to sponsor investigations of any problem which, in its judgment, is critical. These investigations should specifically include fundamental research problems in the pertinent fields of science, applied and developmental problems, operations research, economic analysis of problems at various levels of government, and educational problems.

The summer study group feels that a number of specific programs are required and should be initiated as soon as possible by the proposed fire group. These suggested programs reflect the potentially broad scope of the work of the fire group. General areas of interest will be discussed in the following paragraphs; specific recommendations for action are given later in this chapter.

At the present time there exists a great body of knowledge concerning fire-prevention and -suppression activities. This information includes areas such as techniques for good public educational programs, good fire-fighting tactics, and good professional training programs. Such information is used well in some areas and not at all in others. One of the important actions of the fire group should be to search for ways and means of achieving the adoption by state and local fire authorities of the best techniques available.

Similarly, the fire group should also encourage the dissemination of fire-prevention information through the available communications media, to reach the general public, and through the support of regular and continuing programs in schools, to reach the young people of the nation.

In any study of fire problems, from the point of view of operations research or economics, it immediately becomes apparent that a tremendous amount of information is available but that this material is often incomplete, nonuniformly reported, or inaccurate, and that pertinent corollary data are often not collected at all. In order to facilitate the useful collection of data, two programs should be initiated. First, sufficient studies of the important economic and operational problems should be carried out to identify the desired information, and second, this information must be increasingly accurate, collected in a consistent and uniform manner.

The economic problems of importance certainly include the determination of the best level and distribution of expenditures for fire-prevention and -suppression measures at national, urban, and personal levels, and the examination of the economic incentives which operate to reduce fire costs. In the latter category, the determination, allocation, and regulation of fire costs, including insurance and taxes, should be studied.

Both the economic and the operations-research studies should be directed at the problem of establishing the best use of fire-fighting funds. For example, there is at present no rational way of determining the relative value of funds spent on fire-prevention work and on fire-fighting equipment. The fact that a great diversity of practices exists in the fire departments of the United States suggests that the best practices may be sorted out by the correct operational analysis. In any event, the techniques of operational

analysis should be used to extract as much information as possible from the fires which annually destroy about 1.5 billion dollars worth of property.

Available techniques should be used to construct model fires and educational "games" for the training of firemen and for the evaluation of new fire-fighting practices.

Controlled burning of condemned structures or selected forest areas can be used to obtain quantitative information of interest in operational research and fundamental and applied research. Information obtained from controlled burns can be an invaluable supplement to information which can also be obtained from hostile fires. A major effort should be made to develop appropriate instrumentation and necessary techniques for this type of investigation.

The fire group should investigate the present national effort in applied research and should support needed work. Because most of the work being done in this field is supported by industrial concerns with immediate objectives in mind, the summer study group feels that supplementary efforts will be necessary.

Finally, the summer study group feels that the present effort in fundamental research is relatively weak. The fire group should support work on fundamental problems covering the entire purview of the group. For example, studies are needed on such fire-related phenomena as pyrolysis, ignition, fire spread, atmospheric interactions, fuel properties, effects of moisture, and extinguishment. The projects should be supported by direct contracts, where possible, but, where necessary, should be carried out by the staff of the fire group.

The fire group should also have the responsibility for translating the results of basic studies, as far as possible, into useful fire-suppression

tools. Thus, the ill-defined area between "fundamental" and "Applied" work should receive particular attention.

As a principal part of the translation mentioned in the last paragraph, the fire group should be responsible for increasing the dissemination of information at all technical levels. The group should hold meetings and support publications with the purpose of bringing the fire problem to the attention of the engineering and scientific community, increasing the exchange of information between scientists, engineers, and professional fire people. Although a technical journal devoted to fire problems may be inappropriate at this time, an abstracting journal such as the Fire Research Abstracts and Reviews serves a very useful function.

In the foregoing discussion, the general problems falling within the purview of the proposed fire group are discussed in general terms. More specific recommendations follow.

Recommendations

I. A fire group should be established within the Federal Government to take overall responsibility for the fire problem. This fire group should note and encourage work not in progress as supported by diverse public and private units; assess progress continually; seek, encourage, and develop new ideas on fire control; arrange for the execution of work not now adequately supported.

For these purposes, the fire group should:

1. consist of a director with an adequate staff of full-time personnel,
2. be given authority and have responsibility to contract for necessary work with universities and nonprofit research groups, industrial concerns, and government organizations, and
3. be provided with a budget adequate for the work.

A first-year budget of $3,000,000 is suggested. Perhaps three times this sum will be needed as the program develops. The fire problem, costing society $5,000,000,000 per year, deserves to be considered along with other national problems of this magnitude at the highest levels--the Departments and Congress. The fire group should, therefore, have authority at this level.

II. The fire group should make use of existing public and private organizations in carrying out its program.

III. The program of the fire group should include the following important activities:

1. Search for ways and means of achieving universal adoption by state and local fire authorities of the best techniques which have been developed by the more progressive states and communities. These include fireman training, prevention measures, and prefire planning.

2. Support public education in fire-prevention measures and fire consciousness. Additional study will be needed to develop specific measures.

3. Collect, organize, analyze, and disseminate data on fires. The most urgent need is a quantitative evaluation of the relative importance of organizational and operational factors in fire control, and their economic consequences. To be useful, pertinent data of adequate accuracy must be collected in a consistent and uniform manner. This will involve state and municipal organizations, and urban and forest fires.

4. Study the economic aspects of fire, including common-pool problems and cost-benefit relationships.

5. Study the effect on total fire cost of the variable factors of fire-control organization and response. These factors include leadership, fire-fighting tactics, prefire planning, and personnel training. To carry through this study, a scale of "fire hazard potential" for area classification and a general measure of "total fire cost" should be developed.

6. Examine the determination, allocation, and regulation of fire costs, including insurance and taxes, required to promote more equitable distribution of costs and to produce an economic incentive to reduce risk.

7. Support a wide variety of fundamental research connected with fire phenomena, such as fuel properties, pyrolysis, ignition, fire spread, atmospheric interactions, effect of moisture, extinguishment, etc.

8. Support those special items of applied research that are of important social consequence but poor economic prospect. These items include special hazards, test methods and standards, and development of new techniques lying between fundamental research and commercial exploitation.

9. Use controlled burning of condemned structures and selected forest areas to acquire data on fundamental fire phenomena and the response of fire to extinguishing agents. Data should also be obtained on the effect of the various organizational and operational factors in (5) above.

10. Develop player-participation games for the training of fire-fighting personnel, for the investigation of fire-fighting techniques, and for the planning of interagency cooperation in fire-suppression activities.

11. Sponsor meetings and publications as required to bring the fire problem to the attention of the scientific and engineering community and to disseminate new knowledge to all interested parties.

Committee on Fire Research

Chairman: Professor H. C. Hottel	Director, Fuels Research Laboratory Massachusetts Institute of Technology Cambridge, Massachusetts
Dr. William H. Avery	Research and Development Supervisor Applied Physics Laboratory The Johns Hopkins University Silver Spring, Maryland
Mr. Horatio Bond	Chief Engineer, National Fire Protection Association Boston, Massachusetts
Mr. A. A. Brown	Director, Division of Forest Fire Research U. S. Forest Service Department of Agriculture Washington, D.C.
Dr. Howard W. Emmons	Professor of Mechanical Engineering Harvard University Cambridge, Massachusetts
Mr. Joseph Grumer	Project Coordinator, Flame Dynamics Explosives Research Laboratory U. S. Bureau of Mines Pittsburgh, Pennsylvania
Mr. J. B. Macauley	Assistant to the Director of Defense Research and Engineering Department of Defense Washington, D.C.
Dr. Walter T. Olson	Chief, Propulsion Chemistry Division Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio
Dr. A. F. Robertson	Chief, Fire Research Section National Bureau of Standards Washington, D.C.

Editor of FIRE RESEARCH ABSTRACTS AND REVIEWS

Dr. Walter G. Berl	Applied Physics Laboratory The Johns Hopkins University Silver Spring, Maryland

Fire Research Conference

Members of the Fire Research Conference serve in an advisory capacity to the Committee on Fire Research. Members of the Committee on Fire Research serve as ex-officio members of the Fire Research Conference.

Chairman: Professor H. C. Hottel

Dr. Keith Arnold	Director, Pacific Southwest Forest and Range Experiment Station U. S. Forest Service Berkeley, California
Mr. J. S. Barrows	Chief, Division Forest Fire Research Intermountain Forest and Range Experiment Station U. S. Forest Service Missoula, Montana
Dean L. M. K. Boelter	School of Engineering University of California Los Angeles, California
Mr. B. P. Botteri	Wright Air Development Division Wright-Patterson Air Force Base, Ohio
Dr. Mathew M. Braidech	Director of Research National Board of Fire Underwriters New York, New York
Mr. C. C. Buck	Assistant Director, Division of Forest Fire Research U. S. Forest Service Department of Agriculture Washington, D.C.
Mr. Clarence F. Castle	Chief, Services Division Properties and Installation Office Assistant Secretary of Defense Washington, D.C.
Mr. DeVer Colson	Meteorologist, Meteorological Physics Section U. S. Weather Bureau Washington, D.C.

Mr. James Duggan	3611 Noyes Avenue, S.E. Charleston, West Virginia
Mr. W. L. Fons	Southern Forest Fire Laboratory U. S. Forest Service Macon, Georgia
Mr. Arthur B. Guise	Technical Director, Research and Development Division Ansul Chemical Company Marinette, Wisconsin
Mr. K. E. Klinger	Chief Engineer, Los Angeles County Fire Department Los Angeles, California
Mr. Harold E. Kuhlman	Chief Engineer, Oklahoma Inspection Bureau Oklahoma City, Oklahoma
Dr. Bernard Lewis	President, Combustion and Explosives Research, Inc. Pittsburgh, Pennsylvania
Mr. James E. Malcolm	Technical Development Branch Office of Chief of Engineers U. S. Army Washington, D.C.
Mr. George Richardson	808 Gist Avenue Silver Spring, Maryland
Dr. Vincent J. Schaefer	3 Schemerhorn Road Schenectady, New York
Mr. A. J. Steiner	Fire Protection Engineer Underwriters' Laboratories, Inc. Chicago, Illinois
Mr. Norman J. Thompson	Millers Hill Road Dover, Massachusetts
Dr. Richard Tuve	Head, Engineering Research Branch Mechanics Division U. S. Naval Research Laboratory Washington, D.C.

Members of scientific and technical advisory boards, committees, and panels of the Division, do not serve as representatives of the organizations or agencies by which they are employed but as individual scientists, technologists, and research workers, contributing their personal scientific knowledge to the Academy-Research Council.

Liaison Representatives to Committee and Conference

Dr. H. T. Hookway	United Kingdom Scientific Mission 1907 K. Street, N.W. Washington, D.C.
Mr. G. W. Shorter	Head of Fire Research Section National Research Council Ottawa 2, Canada

Members of the Staff

D. W. Thornhill, Executive Secretary

Emma Jane Whipple, Administrative Assistant

Distribution

Office of Civil and Defense Administration

Walmer Strope, Director of Research

U. S. Forest Service

Edward P. Cliff, Chief

Department of Defense Research and Engineering

Harold Brown, Director

National Bureau of Standards

A. V. Astin, Director

National Science Foundation

Samuel Seely, Head Engineering Section

Members of the Committee on Fire Research

Members of the Fire Research Conference

Liaison to the Committee and Conference

National Academy of Sciences-National Research Council

President, National Academy of Sciences

Chairman, Division of Engineering and Industrial Research

Chairman, Division of Physical Sciences

Chairman, Division of Biology and Agriculture

Chairman, Division of Chemistry and Chemical Technology

National Academy of Sciences-National Research Council

The National Academy of Sciences-National Research Council is a private, non-profit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare.

The Academy itself was established in 1863 under a Congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the Federal Government in scientific matters. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency.

The National Research Council was established by the Academy in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the Academy in service to the nation, to society, and to science at home and abroad. Members of the National Research Council receive their appointments from the President of the Academy. They include representatives nominated by the major scientific and technical societies, representatives of the Federal Government, and a number of members-at-large. In addition, several thousand scientists and engineers take part in the activities of the Research Council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contributions, grant, or contract, the Academy and its Research Council thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the Government, and to further the general interests of science.

The Committee on Fire Research and the Fire Research Conference function within the Division of Engineering and Industrial Research of the National Academy of Sciences-National Research Council, to stimulate and advise on research directed toward the development of new knowledge and new techniques that may aid in preventing or controlling wartime and peacetime fires. The Committee and Conference were established in December of 1955 at the request of the Federal Civil Defense Administration. They are supported by the Office of Civil Defense, Department of Defense, the U. S. Department of Agriculture through the Forest Service, the Department of Defense, the National Science Foundation, and the National Bureau of Standards.